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SHEATHED-ELEMENT GLOW PLUG HAVING AN IONIC CURRENT  
SENSOR AND METHOD FOR OPERATING SUCH A SHEATHED-  
ELEMENT  
GLOW PLUG

FIELD OF THE INVENTION

The present invention relates to a ceramic sheathed-element glow plug for a diesel engine having an ionic-current sensor.

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BACKGROUND INFORMATION

German Published Patent Application No. 34 28 371 describes a ceramic sheathed-element glow plug that includes a ceramic heating element. The ceramic heating element bears an electrode made of a metallic material which is used to determine the electric conductivity of the ionized gas present in the combustion chamber of the internal combustion engine. In this case, the combustion chamber wall is used as the second electrode.

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Furthermore, sheathed-element glow plugs are known which have a housing in which a rod-shaped heating element is disposed in a concentric bore hole. The heating element is made of at least one insulating layer, as well as a first and a second lead layer, the first and the second lead layers connected via a bar at the tip of the heating element on the combustion chamber side. The insulating layer is made of electrically insulating ceramic material, and the first and second lead layers, as well as the bar, are made of electroconductive ceramic material.

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SUMMARY OF THE INVENTION

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The ceramic sheathed-element glow plug of the present invention with ionic-current sensor has an advantage that the sheathed-element glow plug

with ionic-current sensor has a very simple design and is inexpensive to manufacture.

5 It is possible to achieve a design of a sheathed-element glow plug if the glow operation and the ionic-current measurement are carried out simultaneously. The electrode for detecting ionic current may be led up to the end of the heating element on the combustion chamber side. The ionic current may be detected in a region of the combustion chamber where the combustion processes takes place in the combustion chamber. It is also illustrated to  
10 design two electrodes to detect ionic current in such a way that the ionic current flows from one electrode to the other electrode, and thus only crosses a region of special interest for the ionic-current measurement. It is shown to use the ceramic composite structure described below for the various heating-element layers, where conductivity and expansion coefficients may be  
15 adapted very well. This also applies for the precursor composites described below.

In the method for operating a sheathed-element glow plug having ionic-current measurement, the ionic-current detection may be provided  
20 during the glowing of the heating element, since it is of interest to detect the combustion process during the start phase of the internal combustion engine.

#### BRIEF DESCRIPTION OF THE DRAWINGS

25 Figure 1 is a longitudinal sectional view of a sheathed-element glow plug of the present invention with ionic-current sensor.

Figure 2 is a schematic longitudinal sectional view through the combustion-chamber-side end of a sheathed-element glow plug of the present invention  
30 with ionic-current sensor.

Figure 3a shows a first schematic longitudinal sectional view through the heating element of a sheathed-element glow plug of the present invention with ionic-current sensor.

5 Figure 3b shows a second schematic longitudinal sectional view through the heating element of a sheathed-element glow plug of the present invention with ionic-current sensor.

10 Figure 4 shows a schematic cross-sectional view through a heating element of a sheathed-element glow plug of the present invention with ionic-current sensor.

#### DETAILED DESCRIPTION

15 Figure 1 illustrates a sheathed-element glow plug of the present invention schematically in longitudinal section. A tubular housing 3, which may be made of metallic material, contains a heating element 5 in its concentric bore hole at the end on the combustion chamber side. Heating element 5 may be made of ceramic material. Heating element 5 may have a first lead layer 7 and a  
20 second lead layer 9, first lead layer 7 and second lead layer 9 made of electroconductive ceramic material. At end 6 of heating element 5 remote from the combustion chamber, first lead layer 7 and second lead layer 9 are connected by a bar 8. In the example embodiment illustrated, the bar 8 may be made of electroconductive ceramic material. First lead layer 7 and second  
25 lead layer 9 may be separated from each other by an insulating layer 11. Insulating layer 11 may be made of electrically insulating ceramic material. The interior of housing 3 is sealed in the direction of the combustion chamber by a combustion-chamber seal 13 surrounding heating element 5 in a ring shape. At the end of heating element 5 remote from the combustion chamber,  
30 first lead layer 7 is connected to a third connection 37. In the direction of the end of the sheathed-element glow plug remote from the combustion chamber, this third connection 37 is connected to terminal stud 19. At its end remote from the combustion chamber, second lead layer 9 has a contact area 12 via

which second lead layer 9 is electrically connected to housing 3 by way of electroconductive combustion-chamber seal 13. Housing 3 is connected to ground. In an example embodiment, contact area 12 may be constructed in such a way that in this region, the electrically insulating glass coating surrounding the end of heating element 5 remote from the combustion chamber is interrupted, and consequently an electrical contact is produced with combustion-chamber seal 13. In another example embodiment, contact area 12 is provided with a metallic coating.

Terminal stud 19 is set apart from the end of heating element 5 remote from the combustion chamber by a ceramic spacer sleeve 27 disposed in the concentric bore hole of housing 3. In the direction of the end remote from the combustion chamber, terminal stud 19 is led through a clamping sleeve 29 and a metal sleeve 31. At the end of the sheathed-element glow plug remote from the combustion chamber, a circular connector 25, which effects the electrical connection, is mounted on terminal stud 19. The end of the concentric bore hole of housing 3, remote from the combustion chamber, is sealed and electrically insulated by a tubing ring 21 and an insulating disk 23.

The present invention is also illustrated in Figure 2. Only the end of a sheathed-element glow plug according to the present invention on the combustion chamber side is illustrated schematically in longitudinal section. Compared to Figure 1, heating element 5 is intersected in a plane transverse to the sectional plane of Figure 1. Here, only insulating layer 11 is visible. Within insulating layer 11 two electrodes 33 and 33' are placed for detecting ionic current which are broadened at end 6 of heating element 5 on the combustion chamber side. In a further example embodiment, electrodes 33 and 33' may also be applied outside on the insulating layer. At the end of heating element 5 remote from the combustion chamber, first electrode 33 for detecting ionic current is connected to a first connection 15. Second electrode 33' for detecting ionic current is likewise connected at the end of heating element 5 remote from the combustion chamber to a second connection 17. First connection 15 and second connection 17 are passed through terminal

stud 19 to the end of the sheathed-element glow plug remote from the combustion chamber. As previously mentioned, first lead layer 7 is connected to terminal stud 19 with the aid of a third connection 37.

5 The arrangement of the various layers of heating element 5 together with the associated connections are illustrated again with reference to Figure 3. Figure 3a illustrates a heating element 5 in longitudinal section. First electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are disposed in insulating layer 11. At the end of heating element 5 remote from the combustion chamber, first electrode 33 for detecting ionic current is connected to first connection 15, and second electrode 33' for detecting ionic current is connected to second connection 17. In addition, at the end of heating element 5 on the combustion chamber side, bar 8 is discernible which connects first lead layer 7 and second lead layer 9 to one another.

10 Figure 3b shows heating element 5 which is intersected in a plane transverse to the plane in which heating element 5, which was illustrated in Figure 3a, is intersected. First lead layer 7 and second lead layer 9 are interconnected via bar 8 at end 6 of heating element 5 remote from the combustion chamber.

15 Third connection 37 is connected to first lead layer 7 at the end of heating element 5 remote from the combustion chamber.

20 Figure 4 shows a cross-section through heating element 5 at the end remote from the combustion chamber. First lead layer 7 is separated from second lead layer 9 by insulating layer 11. Arranged within insulating layer 11 is first connection 15 which is connected to first electrode 33 for detecting ionic current. Likewise arranged within insulating layer 11 is second connection 17 which is connected to second electrode 33' for detecting ionic current. Third connection 37 is disposed within first lead layer 7. To better accommodate and insulate first and second electrodes 33, 33' for detecting ionic current, the insulating layer is broadened in the region in which these electrodes are arranged.

In a first example embodiment, the sheathed-element glow plug may be operated in such a way that during the start of the internal combustion engine, the sheathed-element glow plug is initially operated in heating mode. During the glow phase, a positive voltage with respect to ground is applied to third connection 37, so that a current flows across first lead layer 7, bar 8 and second lead layer 9. Due to the electrical resistance on this path, the temperature of the heating element rises, and the combustion chamber, into which the end of the sheathed-element glow plug on the combustion chamber side extends, is heated. After ending the glow phase, a voltage potential is applied to first connection 15 and second connection 17, so that first electrode 33 and second electrode 33' are used as electrodes for measuring ionic current. If the combustion chamber is ionized due to the presence of ions, then an ionic current may flow from electrodes 33, 33' for detecting ionic current to the combustion-chamber wall which is grounded. In this example embodiment, first electrode 33 for detecting ionic current and the second electrode for detecting ionic current act as electrodes at the same potential in parallel.

In a further example embodiment, a different voltage potential may be applied to first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current so that an ionic current flows between first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current.

In another example embodiment, the glow operation and the detection of ionic current may be carried out simultaneously by the sheathed-element glow plug. The voltage for the glow operation and for detecting ionic current is applied simultaneously to third connection 37 and to first and second connections 15, 17, respectively. The voltage potentials may be selected such that first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are at the same or different potential, as described above, the ionic current flows via the ionized combustion chamber to the combustion chamber wall, or from first electrode 33 for detecting ionic

current via the ionized combustion chamber to second electrode 33' for detecting ionic current.

5 In a first example embodiment, the materials of first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and electrode 33 for detecting ionic current, as well as second electrode 33' for detecting ionic current may be made of ceramic material. This ensures that the thermal expansion coefficients of the materials scarcely differ, thus guaranteeing the endurance strength of heating element 5. The material of first lead layer 7, bar 8 and 10 second lead layer 9 is selected such that the resistance of these layers is less than the resistance of insulating layer 11. The resistance of first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current is less than the resistance of insulating layer 11.

15 In a further example embodiment, first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current may also be made of metallic material, e.g. platinum.

20 In another example embodiment, first lead layer 7, bar 8 and second lead layer 9, insulating layer 11 and possibly first electrode 33 and second electrode 33' are made of ceramic composite structures which contain at least two of the compounds  $Al_2O_3$ ,  $MoSi_2$ ,  $Si_3N_4$  and  $Y_2O_3$ . These composite structures are obtainable by a one-step or multi-step sintering process. The specific resistance of the layers may preferably be determined by the  $MoSi_2$  content and/or the grain size of  $MoSi_2$ ; the  $MoSi_2$  content of first lead layer 7, 25 of bar 8 and of second lead layer 9, as well as of first and second electrodes 33, 33' for detecting ionic current may be higher than the  $MoSi_2$  content of insulating layer 11.

30 In a further example embodiment, first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and possibly first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are made of a composite precursor ceramic having different portions of fillers. The matrix of this



material is made of polysiloxanes, polysesquioxanes, polysilanes or polysilazanes which may be doped with boron, nitrogen or aluminum and are produced by pyrolysis. At least one of the compounds  $Al_2O_3$ ,  $MoSi_2$ ,  $SiO_2$  and SiC forms the filler for the individual layers. Analogous to the composite structure indicated above, the  $MoSi_2$  content and/or the grain size of  $MoSi_2$  may determine the resistance of the layers. The  $MoSi_2$  content of first lead layer 7, of bar 8 and of second lead layer 9, and possibly of first and second electrodes 33, 33' for detecting ionic current may be set higher than the  $MoSi_2$  content of insulating layer 11. In the example embodiments indicated above, the compositions of first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and possibly of first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are selected such that their thermal expansion coefficients and the shrinkages occurring during the sintering and pyrolysis processes are identical, so that no cracks develop in heating element 5.